# Elemental Composition of Wisconsinan Tills of the Lower Cuyahoga Valley, Northeastern Ohio[1]

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ABSTRACT. Inductively-coupled plasma (ICP) analyses were performed on 25 selected till samples of varying ages from the Lower Cuyahoga Valley in northeastern Ohio. Samples of the ≤0.074-mm fraction from the Lavery, Kent, Northampton, and Mogadore Tills were analyzed for phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn), iron (Fe), boron (B), copper (Cu), zinc (Zn), aluminum (Al), and sodium (Na). Statistical tests showed some significant differences in elemental means among individual till units. Manganese, Fe, and Cu were not significantly different among any of the till units. Bivariate regressions showed that most elemental concentrations correlated to grain size. Zinc was associated with the sand size-fraction; Fe was associated with the silt-size fraction; Ca, Mg, B, Al, and Na were associated with the clay-size fraction; and P, K, Mn, and Cu had no preferred association with any one grain size. Elemental differences among the tills resulted from variations in source area and local materials. Based on elemental composition, the Kent Till is similar to the Mogadore Till, and the Lavery Till is similar to the Northampton Till. The sandy Kent and Mogadore Tills may have a similar northeastern source area which was low in overall carbonate content. The clay-rich Lavery and Northampton Tills have somewhat similar mineral contents, possibly suggesting a more northwesterly carbonate-dominated source in the Erie Basin.

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## INTRODUCTION

Criteria often used to correlate tills include field descriptions and laboratory analyses. Characteristics of tills observed in the field are: texture, color, structure, consistency, reaction to hydrochloric acid, and pebble abundance and lithology. Laboratory characteristics are grain size, carbonate content, clay-mineral composition, and sand lithologies. Often these are useful in distinguishing among tills; in other cases there may be considerable overlap among tills. Shepps (1953) correlated tills of northeastern Ohio by using their matrix texture; this has become a primary method of correlation. Totten (1960) demonstrated that quartz-feldspar ratios of the fine sand fraction in tills could be used to distinguish among different tills in northeastern Ohio. Szabo and Ryan (1981) differentiated among tills using carbonate content determined by a Chittick apparatus. The proportions of illite to kaolinite and chlorite in unweathered till samples were used by Szabo and Fernandez (1984) to distinguish among tills of the Cuyahoga Valley in northeastern Ohio.

The use of elemental analyses to discriminate among tills is not very common. Wilding et al. (1971) studied clay mineralogy and elemental composition of till-derived soils in west-central Ohio and suggested that differences in composition were due to the intensity of weathering. May and Dreimanis (1973) differentiated tills in southern Ontario and demonstrated that Erie-Ontario lobe tills differed from those of the Huron-Georgian Bay lobe on the basis of copper, zinc, chromium, and nickel.

The major purpose of this study was to determine the elemental composition of tills in the lower Cuyahoga Valley using inductively-coupled plasma (ICP) analysis. Data were used to: (1) determine significant differences in composition among various Wisconsinan tills; (2) determine the relationship of composition to grain size; (3) examine the relationship of elemental composition to carbonate content; and (4) analyze the effect of bedrock on tills.

STUDY AREA. The study area (Fig. 1) is located in the glaciated lower Cuyahoga Valley in Summit and Cuyahoga counties in northeastern Ohio, and includes the entire Cuyahoga Valley National Recreation Area (CVNRA). The recreation area is located between Akron and Cleveland and follows the Cuyahoga Valley from Bath Road in Northampton and Bath townships in Summit County north to Rockside Road in Valley View and Independence in Cuyahoga County. The rocks forming the uplands adjacent to the Cuyahoga Valley are Pennsylvanian Sharon Sandstone in the southern part and Mississippian Cuyahoga Formation and Berea Sandstone in the northern part (Fernandez 1983). Rocks in the valleys consist of the Bedford Shale and Cleveland Shale in the north, and the Cuyahoga Formation in the south (Frank et al. 1958).

PREVIOUS STUDIES. Pleistocene deposits of the Cuyahoga Valley have been studied for over 100 years. Claypole (1887) examined the deposits of ancient Lake Cuyahoga. In 1902, Leverett published a monograph describing thickness, distribution, age, and morphology of tills of the Erie and Ohio basins. He refined his original work in a later publication (Cushing et al. 1931). During the past 50 years, White (1982) mapped surficial features and developed the Pleistocene stratigraphy of northeastern Ohio. He also mapped glacial deposits in northwestern Pennsylvania (White et al. 1969) and demonstrated the continuity of the stratigraphy there with that of Ohio. Rau (1969) discussed the drainage evolution of the Cuyahoga River.

Several stratigraphic studies in the Cuyahoga Valley were done as M.S. theses at The University of Akron and at Kent State University. Wittine (1970) analyzed lacustrine silts of the Cuyahoga Valley north of Akron and correlated them to several phases of Lake Cuyahoga. Bain (1975) examined deltaic deposits and terraces between Akron and Peninsula. The studies of Ryan (1980), Angle (1982), Donovan (1983), Ospanik (1983), and Fernandez

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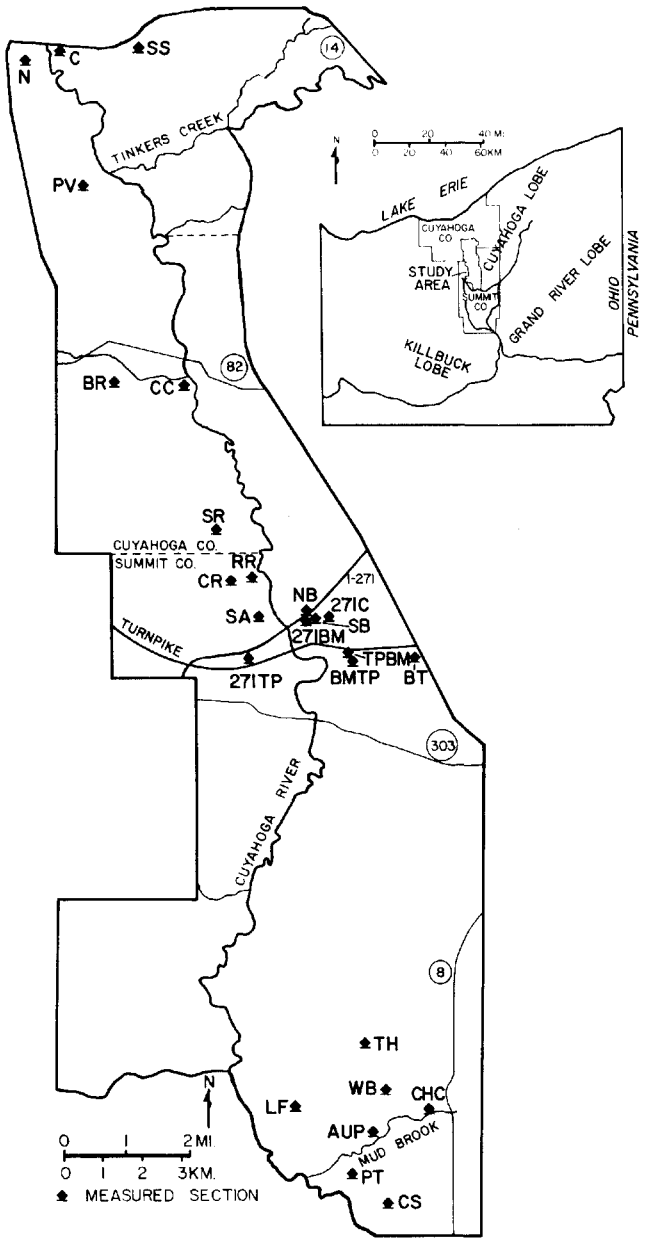


FIGURE 1. Study area showing location of measured sections in the lower Cuyahoga Valley (modified from Szabo and Fernandez 1984).

(1983) have permitted correlation of deposits in the Cuyahoga Valley to the classical stratigraphy of White (1982). Their results are summarized in Szabo and Ryan (1981), Szabo and Angle (1983), and Szabo and Fernandez (1984).

The spatial arrangement of Pleistocene deposits within the Cuyahoga Valley is illustrated in Figure 2. These deposits include tills, silts, sands, and gravels of Wisconsinan age (Ryan 1980). The upland tills in the area are the Late Wisconsinan Hiram, Lavery, and Kent Tills. Hiram Till is very thin and restricted to hilltops; Lavery Till has a wide areal distribution (White 1982) and is underlain mostly by Northampton Till (Fernandez 1983) and infrequently sandstone (Szabo and Angle 1983). Tills in the Cuyahoga Valley and its tributaries consist of two beds of Northampton Till (Fernandez 1983) and/or a bed of Mogadore Till (Ryan 1980), both of which are assigned tentatively to the Middle Wisconsinan. Both the Northampton Till and the older Mogadore Till may overlie silt or bedrock.

## MATERIALS AND METHODS

Samples were collected from four sections in the Cuyahoga Valley (Fig. 1): Cedar Hill Circle and Woodbrook East described by Ryan (1980), and Substation and Canal Road measured by Fernandez (1983). The northernmost, Canal Road Section (C), is located on a west-facing slope 60 m south of the Canal Road Rockside Road intersection. (Fig. 1). Eight and one-half meters of olive gray to dark gray unoxidized Northampton Till lies between lacustrine sediments. Samples used in this study averaged 9% sand, 43% silt, and 48% clay (Fernandez 1984).

The Substation Section (SS) is located in a westward-draining ravine at the base of a fly ash dump 1030 m southwest of the intersection of Rockside and Turney Roads (Fig. 1). Kent Till at this section is a blocky, pebbly, brown, sandy till (1.75 m thick) that overlies Northampton Till. Samples of Kent Till contain 35% sand, 50% silt, and 15% clay (Fernandez 1984).

The Cedar Hill Circle Section (CHC) (Ryan 1980) is located along the north bank of Mud Brook across from an outcrop of Sharon Sandstone 640 m west of Akron-Cleveland Road in Northampton Township (Fig. 1). The section is composed entirely of firm, dark gray Mogadore Till (20 m thick). The texture of samples used in this study averaged 30% sand, 53% silt, and 17% clay (Ryan 1980).

The fourth section, Woodbrook East (WB), is located on the west wall of an abandoned gravel pit at the end of Woodbrook Street in Northampton Township (Fig. 1). This section contains two tills that were sampled during this study. Dark yellowish-brown Lavery Till containing secondary carbonate overlies 0.75 m of yellowish-brown sand, which is underlain by dark yellowish-brown to dark gray Northampton Till. Samples of the Lavery Till contain 8% sand, 46% silt, and 46% clay, whereas those of Northampton Till have 6% sand, 52% silt, and 42% clay (Ryan 1980).

TABLE 1

*Results of one-way ANOVA. Significant values (*) of F probability must ≤0.05.*

| Element | Mean squares within | Mean squares between | *F* | *F* probability |
|---|---|---|---|---|
| P | 122,660 | 102,259 | 0.83 | 0.52 |
| K | 5,421,766 | 25,881,354 | 4.77 | 0.01* |
| Ca | 61,930,026 | 2,037,212,155 | 32.90 | 0.00* |
| Mg | 1,591,566 | 57,743,434 | 32.28 | 0.00* |
| Mn | 2,864 | 3,609 | 1.26 | 0.32 |
| Fe | 11,003,190 | 9,099,679 | 0.83 | 0.52 |
| B | 84 | 2,189 | 26.14 | 0.00* |
| Cu | 543 | 231 | 0.43 | 0.79 |
| Zn | 103 | 2,388 | 23.21 | 0.00* |
| Al | 28,680,008 | 340,336,906 | 11.87 | 0.00* |
| Na | 3,102 | 60,267 | 19.43 | 0.00* |

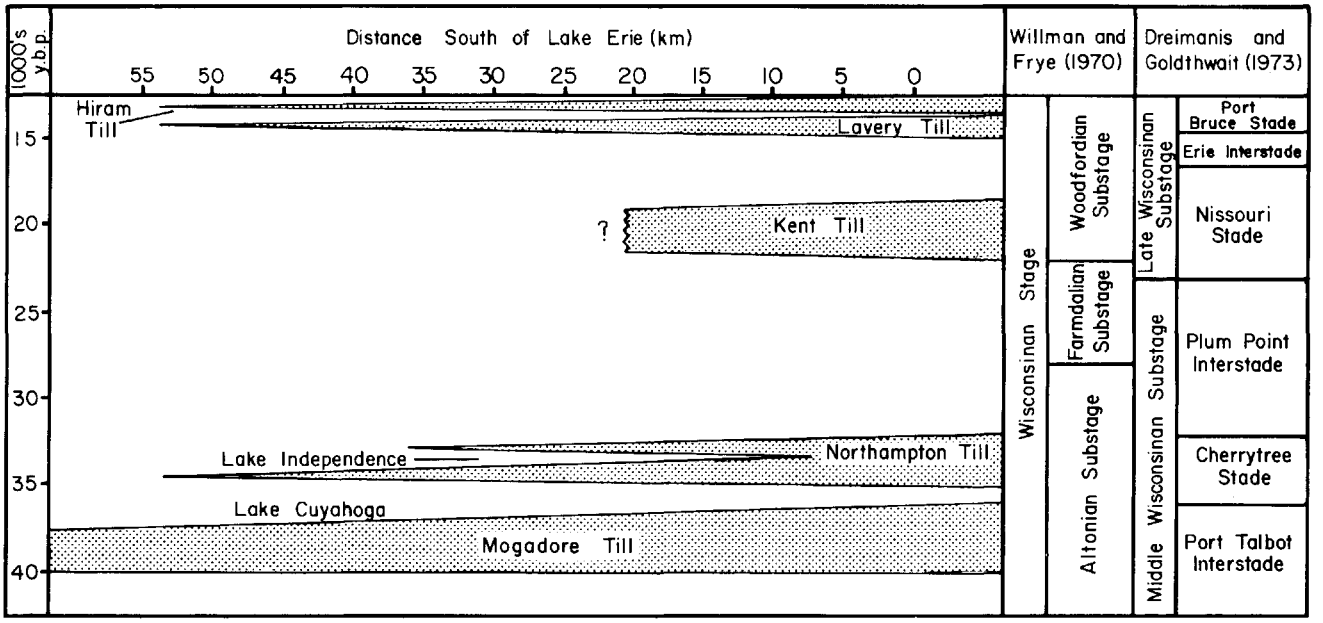


FIGURE 2. Diagrammatic stratigraphy of Wisconsinan deposits of the lower Cuyahoga Valley (modified from Szabo and Fernandez 1984).

Samples from the four sections were disaggregated in a mortar and sieved to less than 0.074 mm. The digestion of samples and ICP analyses were performed at the Ohio Agricultural Research and Development Center (OARDC) in Wooster, Ohio. The center used a nitric acid ($HNO_3$)/perchloric acid ($HClO_4$) digestion technique to prepare samples for ICP analysis. Three hundred milligrams of each sample were weighed and placed into 75-ml digestion tubes. Three milliliters of a 1:1 mixture of $HNO_3$ and $HClO_4$ were added to each container, and the contents were allowed to stand overnight. Before digestion, a small funnel was placed in the top of each tube to act as a condenser. Each sample was heated on a Technicon block for 2 h at 130°C, and for 2 additional h at 205°C. After heating, each sample was transferred to a 10-ml volumetric flask and diluted to volume with deionized water. A Bausch and Lomb ICP unit (Model Q37) was used to determine the amount of phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn), iron (Fe), boron (B), copper (Cu), zinc (Zn), aluminum (Al), and sodium (Na) in each sample.

An analysis of variance (ANOVA) was used to test for significant elemental differences among all tills (Nie et al. 1975). The $F$-statistic was calculated by dividing the between-groups variance by the within-groups variance. This statistic was compared to tabular $F$-values. Calculated $t$-values were compared to tabular values (Ferguson 1971) with a one-tailed test and $P$ set at 0.05. If the probability of the calculated $F$-value was less than 0.05, it was assumed that a significant difference existed among till units for that particular element.

After the significant elements were determined, $t$-tests (Nie et al. 1975) were used to find significant elemental differences between various combinations of tills by comparing their elemental mean values. Calculated $t$-values were compared to tabular values (Ferguson 1971) with a two-tailed test and $P$ set at 0.05. If the calculated value exceeded the tabled value, it was assumed that a significant difference existed between tills for that given element.

Regression analysis (Nie et al. 1975) was used to determine correlation coefficients between the amounts of various elements and grain size. This method was also used to compare calcium content, determined by ICP analysis, to that calculated from Chittick gasometric analysis. Significant correlation coefficients had $P$ set at 0.05.

## RESULTS

The results of ICP analysis form a 25 × 11 matrix. This matrix is not included in this paper, but is available from the authors on request. The ANOVA was applied to the matrix and showed that 7 of the 11 elements analyzed needed further statistical analysis (Table 1). The seven were K, Ca, Mg, B, Zn, Al, and Na.

The means for the seven elements also were tested for various till combinations (Table 2). The composition of the Lavery Till was different than that of the Kent Till for five of seven elements. When the Lavery Till was compared to the Northampton Till, there were conflicting results. Samples for the north (C) had significantly ($P < 0.05$) different means for four elements, whereas those from the south (WB) differed only on the basis of calcium. Samples of Lavery Till also differed for four of seven elements, when compared to samples of Mogadore Till.

Kent Till appeared to be quite different from Northampton Till but similar to Mogadore Till. Samples of Northampton Till from C had six of seven elemental means that differed significantly ($P < 0.05$); those from WB had five of seven. Sodium was the only element that distinguished Kent Till from the Mogadore Till.

When the combinations of Middle Wisconsinan Tills were compared, Northampton Till at C differed only in K content from the same till at WB. Both sets of Northampton Till samples differed from those of Mogadore Till for five of seven elements (Table 2).

TABLE 2

*Results of t-tests comparing various pairs of till. Significant comparisons are indicated by asterisks.*

| Till combination | Element | | | | | | |
|---|---|---|---|---|---|---|---|
| | K | Ca | Mg | B | Zn | Al | Na |
| Lavery-Kent | | * | | * | * | * | * |
| Lavery-Northampton (C) | | * | * | * | | | * |
| Lavery-Northampton (WB) | | * | | | | | |
| Lavery-Mogadore | | * | * | * | * | | |
| Kent-Northampton (C) | * | | * | * | * | * | * |
| Kent-Northampton (WB) | | | * | * | * | * | * |
| Kent-Mogadore | | | | | | | * |
| Northampton (C)-(WB) | * | | | | | | |
| Northampton (C)-Mogadore | | * | * | * | * | | * |
| Northampton (WB)-Mogadore | | * | * | * | * | | * |

TABLE 3

*Correlation coefficients between grain size and various elements. Significant values ($r > 0.40$; $P = 0.05$) are indicated by asterisks.*

| Size | Element K | Ca | Mg | B | Zn | Al | Na |
|---|---|---|---|---|---|---|---|
| Sand | −0.21 | −0.68* | −0.79* | −0.84* | 0.80* | −0.69* | −0.73* |
| Silt | −0.44* | −0.26 | −0.37 | 0.13 | 0.12 | 0.08 | −0.10 |
| Clay | 0.34 | 0.71 | 0.86* | 0.73* | −0.77* | 0.60* | 0.70* |

Because some elements might be contained primarily in certain size fractions of till matrix, the amounts of the seven significant elements were compared with the sand, silt, and clay percentages of their respective samples (Table 3). Most of the sand fraction (0.0625 − 2 mm) was not included in the ICP analysis; however, a comparison between amounts of elements and the sand fraction was still made. This is not entirely valid, but the percentages of sand, silt, and clay totalled 100%. Thus, if silt and clay percentages are known, the sand percentage can be calculated. This dilemma is known as a closure problem and is difficult to avoid and often ignored (Davis 1986). In this study, the problem is ignored because five of seven elements showed strong positive correlation with the clay fraction. Potassium had a weak correlation with silt, and only Zn had a strong inferred correlation to sand. Katzmark (1985) demonstrated that the relationships for the combined samples illustrated in Table 3 are also valid for individual tills.

## DISCUSSION

Sitler (1963) described a large number of minerals found in tills of northeastern Ohio. Many of these minerals contribute to the elemental composition of the tills, but common rock-forming minerals probably are responsible for the bulk composition of tills. The sources of calcium in till are carbonates, plagioclase, pyroxene, hornblende, and some clay minerals. Dolomite, pyroxene, hornblende, biotite, chlorite and other clay minerals contribute magnesium. Aluminum has a variety of sources, but the major portion originates in clay minerals and feldspars. Sodium is found in feldspars, hornblende, augite, and clay minerals. Boron may be associated with clays. Potassium occurs in orthoclase, muscovite, and clays. Zinc has a concentration which is similar to that of Paleozoic rocks (Warren and Delavault 1961).

Variations in the proportions of these minerals are expressed partially as differences in texture and composition of tills. In the present study, Ca, Mg, B, Al, and Na were associated with the clay size-fraction. Most Ca and some Mg probably occurred in carbonates in the clay fraction (Fig. 3). Katzmark (1985) found high correlations between calcium carbonate but a lesser degree of correlation between magnesium and carbonate. Calcium also may be held in cation exchange sites in clay minerals. The correlation of Mg and carbonate is less because Mg is a major component of chlorite, a dominant clay mineral in tills of the Cuyahoga Valley (Szabo and Fernandez 1984). Boron may occur as an interlayer cation and Na may be held in a cation exchange site. Some K is contained in illite. Most Al is contained in the chlorite and illite.

The elemental analysis of tills may be applied to interpret the source rocks and possible source areas of tills of

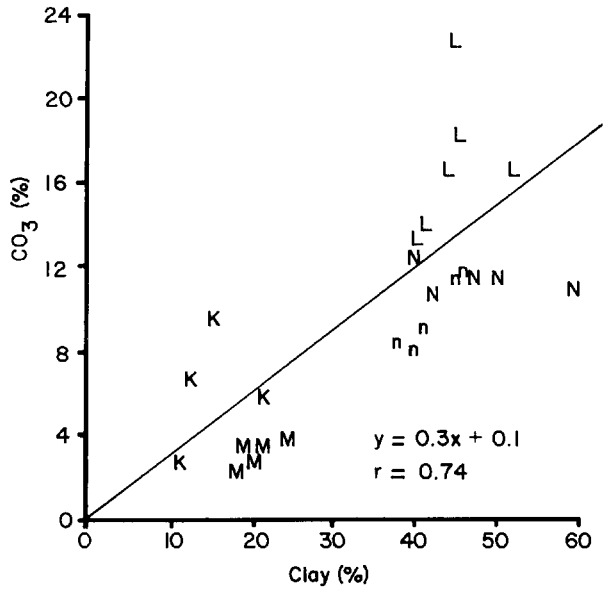


FIGURE 3. Linear regression equation and correlation coefficient for carbonate content vs. clay content. M, Mogadore Till; K, Kent Till; n, Northampton Till (WB); N, Northampton Till (C); L, Lavery Till.

the lower Cuyahoga Valley. Lavery Till was significantly higher in Ca than other tills, and was significantly higher in B than Kent, Northampton (C), and Mogadore Tills. The higher Ca content in Lavery Till is attributed to the fact that this till had the highest carbonate content of all the tills in this study. The high B content was correlated to the high clay content of Lavery Till. The source material for Lavery Till is probably extra-local Devonian siltstones, shales, and carbonates or more distant Silurian carbonates in the eroded western Erie Basin.

Kent Till was lower in Na than other tills and was higher in Zn and lower in Al and B than Lavery and Northampton Tills. Lower Na, B, and Al contents were associated with the low clay content of Kent Till. Thus, a north or northeastern source consisting of Mississippian and Devonian silici-clastic rocks exposed along the edge of the Allegheny Plateau most likely provided material for Kent Till.

Northampton Till (C) was higher in Mg and Na than Lavery, Kent, and Mogadore Tills. It also was higher in B than Kent and Mogadore Tills but lower in B than Lavery Till. High Mg content was associated with the high carbonate and chlorite content of Northampton Till. Boron was higher because of the high clay content of Northampton Till, when compared to Kent and Mogadore Tills. Northampton Till (C) was similar to Northampton Till (WB) except for the lower K at WB. A possible explanation for this is that till at WB may be

slightly weathered, and K may have been leached (Szabo and Fernandez 1984). The source rock for the Northampton Till probably also included Devonian clastics and carbonates and Silurian carbonates.

Mogadore Till was lower in Ca, Mg, and B and higher in Zn than Lavery and Northampton Tills. Mogadore Till was higher in Na than Kent Till, but lower in Na than Northampton Till. Low Ca and Mg contents correlated with low carbonate content, whereas low B and Na contents correlated to its low clay content. Because the Mogadore Till is the oldest till exposed in the CVNRA (Szabo and Ryan 1981; Szabo and Angle 1983; Szabo and Fernandez 1984), it is possible that more local silici-clastic bedrock has been incorporated into it than into the younger tills. The dominant clasts in this till are sandstone and siltstone.

Two results of the present study were unexpected. The first was the positive correlation of overall carbonate content to clay content. Kemmis and Hallberg (1980) showed that carbonate content was inversely proportional to clay content in southeast Iowa. They attributed this relationship to the carbonate minerals of local bedrock being comminuted to their terminal grade sizes (Dreimanis and Vagners 1971). This relation is not true in the lower Cuyahoga Valley and may be interpreted to mean that the carbonate part of the till matrix may represent a more distant regional source area in the Erie Basin rather than a local source as in the case of southeastern Iowa.

The second result was the high correlation between Ca from ICP analysis and that determined from Chittick data (Fig. 4). Generally, the Ca values from ICP analysis were higher than those from Chittick analysis (Katzmark 1985). The higher values are attributed to other sources of Ca such as plagioclase. Correlation coefficients calculated for the Mogadore and Northampton (WB) Tills individually are significantly less than those for combined data (Katzmark 1985). These tills have a high plagioclase content (Ryan 1980), which suggests that more Ca is possibly coming from plagioclase causing a lesser degree of correlation.

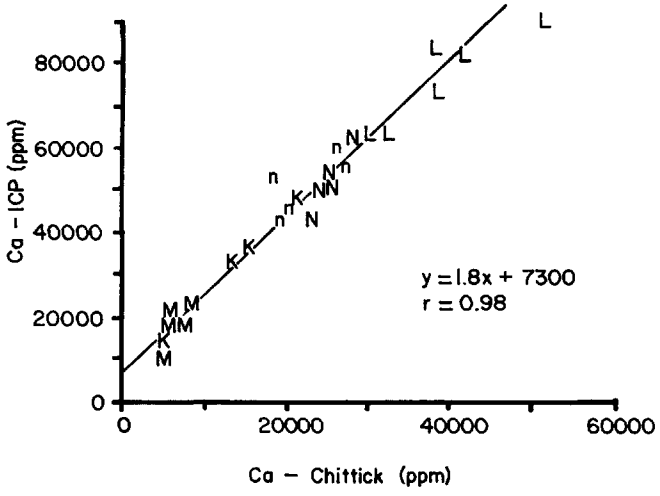


FIGURE 4. Linear regression equation and correlation coefficient for calcium determined by ICP analysis vs. calcium determined by a Chittick apparatus. Abbreviations are as in Figure 3.

This study shows that two different sources may have existed for Wisconsinan Tills. The first is that ice from a northerly or northeasterly source low in carbonates probably incorporated much local silici-clastic rocks before depositing Mogadore and Kent Tills. The second is that ice from a more northwesterly source higher in carbonates, shales, or older lacustrine sediments may have deposited the Northampton and Lavery Tills. More studies are needed to determine why the source areas may have alternated during the Wisconsinan.

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